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FACILITATED WORKSHOP ON CLEAN-UP ACTIONS IN INHABITED AREAS IN FINLAND AFTER AN ACCIDENTAL RELEASE OF RADIONUCLIDES

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Key words: nuclear emergency management, clean-up actions, decision support, multiattribute risk analysis, key player participation

Abstract

Clean-up actions in inhabited areas cannot be undertaken without dialogue and consensus between the stakeholders and inhabitants in the contaminated area. In this report, possible clean-up strategies are studied in a hypothetical radiation accident at a nuclear power plant. The effectiveness to reduce the dose, the monetary costs of actions, workers risks and actions feasibility were assessed. The clean-up strategies were analysed in a facilitated workshop which was attended by all key players in order to find out the most appropriate strategies to protect the public, the workers and the environment.

The participants rated the workshop method very valuable. The most adequate clean-up strategy was found and agreed upon; during the workshop the participants were even able to improve the outcome by modifying the strategy options prepared in advance. The positive feedback and high commitment to the work could be a result from the transparent process and the fact that many participants were local inhabitants in the most 'contaminated' area. This emphasized the importance of local public participation in the environmental decision-making process.

SINKKO Kari, AMMANN Michael, HÄMÄLÄINEN Raimo P., MUSTAJOKI Jyri. Ydinonnettomuuden jälkeen asuinalueilla tehtävien puhdistustoimenpiteiden analysointi päätösriihimenetelmällä. STUK-A214. Helsinki 2005, 54 s.

Avainsanat: ydinonnettomuustilanteiden hallinta, puhdistustoimenpiteet, päätöksenteon tuki, moniattribuuttiriskianalyysi, sidosryhmien osallistuminen

Tiivistelmä

Ydin- tai säteilyonnettomuuden jälkeen asuinalueilla tehtäviä puhdistustoimenpiteitä ei voi tehdä ilman sidosryhmien ja paikallisen väestön välistä dialogia ja yhteisymmärrystä. Tässä raportissa on tutkittu oletetun ydinvoimalaitosonnettomuuden jälkeen tehtäviä puhdistustoimenpidestrategioita. Työssä on arvioitu mahdollisten toimenpiteiden tehokkuus vähentää annosta, työntekijöiden riskit, toimenpiteiden kustannukset ja toteuttamiskelpoisuus. Toimenpidestrategiat analysoitiin päätösriihessä, johon osallistuivat kaikki avainhenkilöt. Tavoitteena oli löytää ne strategiat, jotka parhaiten suojelevat väestöä, työntekijöitä ja ympäristöä.

Riiheen osallistujat arvottivat päätösriihimenetelmän hyvin hyödylliseksi. Tunnistettiin ja sovittiin parhaimmasta strategiasta; riihen aikana osallistujat jopa modifioivat etukäteen valmisteltuja toimenpidevaihtoehtoja ja löysivät paremman strategian. Saatu positiivinen palaute riihestä ja sitoutuminen työskentelyyn seurannevat avoimesta päätöksentekoprosessista ja varsinkin siitä, että monet osallistujat olivat oletetun pahimmin saastuneen alueen asukkaita. On tärkeää, että paikallinen väestö voi osallistua ympäristöään koskevaan päätöksentekoon.

Contents

1 Introduction

As a consequence of a major nuclear accident, thousands of square kilometres may be unevenly contaminated by a radioactive fallout, and various protective actions might be needed to reduce the dose to the public from the deposited radionuclides. In inhabited areas, a broad range of surfaces is contaminated by the radioactive fallout: exteriors and interiors of buildings, streets, trees, bushes and lawns in parks and gardens. The contamination level varies depending on the release composition, prevailing weather at the time of the fallout, and on the surface. Precipitation causes generally higher total deposition. Dry deposition contaminates predominately roofs, streets, leaves of trees, bushes and lawns. Rain washes these surfaces and contaminants accumulate on the ground and in the sewage system. In addition to deliberate decontamination, regular cleaning and natural processes, such as precipitation, transport of contaminants from building surfaces to the topsoil, and from the topsoil into the deeper layers. Such processes together with the radioactive decay will reduce the dose-rate in the course of time.

From the radiation protection point of view the aim of protective actions is to reduce the individual as well as the collective dose to the public and at the same time to prevent any unnecessary increase in the dose of workers carrying out the recovery operations. It is also desired to reduce radiological impacts on the environment, to bring the contamination under control, and to keep the area in or return it back into unrestricted use by feasible decontamination measures.

A comprehensive overview of the major methods to clean-up large areas is available in the literature (Andersson 1996, Andersson and Roed 1999, Andersson et al. 1995 and 2003, Brown et al. 1996, IAEA 1989, Lehto 1994). The successful implementation of the actions, however, requires adequate knowledge of the situation and good planning including the identification of those issues that the stakeholders and the population of the contaminated areas wish to consider when choosing and implementing the actions. The international organisations in radiation protection have also emphasized that the basis for the decision must be perceived by the public, and all relevant factors concerning the decision should be considered in a rational manner, i.e. the actions should be justified and optimised (ICRP 2000). The facilitated workshop method employs a group process where responsibility is placed on participants to assimilate the information and to provide judgements. Decision analytical methods applied in the workshops are used to identify the objectives, criteria or performance measures and to assess their relative importance to the decision. The aim is to create better alternatives for decisions and get a structured overall view of the problem. Consequently, the decisions to be made will be transparent and justifiable.

Decision analysis techniques have been applied to improve the understanding of social and environmental decisions in problems dealing with such issues as wastewater treatment and wilderness preservation (McDaniels 1996; McDaniels and Roessler 1998). Gregory and Keeney (1994) organised a workshop to elicit the stakeholders' values and used these as a basis for creating an improved set of alternatives whether to permit the development of a coal mine in an isolated pristine tropical rain forest. Marttunen and Hämäläinen (1995) applied decision analysis during computer supported interviews and involved a large number of stakeholders in two river development projects. The papers by Apostolakis and Pickett (1998), Hämäläinen (1988, 1990, 1992), Hämäläinen and Karjalainen (1992), Keeney and von Winterfelt (1993) and Keeney (1980) are examples of studies that deal with the clean-up of a hazardous waste site, energy policy of nuclear power and management of nuclear waste. Facilitated workshops have earlier been successfully applied, e.g. after the Chernobyl accident and in the planning of protective actions in hypothetical radiation accidents, to find out appropriate interventions (Albrecht et al. 1997; Aumonier and French 1992; Bartzis et al. 1999; French et al. 1996; Hämäläinen et al 2000; International Chernobyl Project 1991; Sinkko et al. 2004; Zeevaert et al. 2001).

The Finnish workshop dealing with clean-up actions in inhabited areas reported here was a part of the EVATECH research project "Information Requirements and Countermeasure Evaluation Techniques in Nuclear Emergency Management" under the key action "Nuclear Fission" of the fifth Euratom Framework Programme (FP5) of the European Commission. The main objectives of EVATECH's national workshops were: (1) to develop methods for stakeholder involvement in exercises and emergency planning; (2) to verify the factors driving the decision making; (3) to explore the information needs of all the parties involved in decision making and (4) to identify those forms of strategy that the relevant organisations wish to consider.

The report is structured in the following way. Chapter 2 describes the events that were assumed to happen during an acute accident phase and the protective actions taken. We only consider those actions that are of relevance for clean-up actions in inhabited areas one week after the accident. Applicable clean-up actions are described in Chapter 3. In addition, tentative strategies for the workshop are suggested for constituting portfolios of different clean-up actions in areas with similar contamination. The tangible attributes, such as doses and monetary costs, are also assessed. Chapter 4 deals with the workshop, its arrangement, the elicitation of attributes, the decision analysis of the problem and discussion of the results. In addition, the participants' evaluation of the workshop is given in this chapter. Chapter 5 contains a discussion of the observations.

2 Day of the hypothetical accident

2.1 Accident scenario

The national workshops arranged within the EVATECH project were based on a hypothetical accident in a typical European PWR (Pressurized Water Reactor) with a large, dry steel containment and about 2000 MW(th) of power. The release scenario was taken from a typical containment failure classification for that type of nuclear power plant (NPP). For the purpose of the Finnish workshop it was assumed that a hypothetical core-damaging and containment leak accident had occurred at the Loviisa NPP, and this led to the contamination of the eastern part of the Uusimaa province. The assumed time of the accident was in the beginning of June, on a working day. The estimated probability of occurrence of such a containment failure accident leading to a significant release is less than one in 1,000,000 per reactor-year for this NPP. The progress of the accident was described as follows (Niemelä 2002):

‘The accident starts with a fire in one of the electrical cabinet rooms causing a successful shutdown of the reactor. An independent failure of the emergency core cooling system and the effects of the fire prevent core cooling. The containment is successfully isolated. Core heat-up starts 3.5 hours after shutdown and one hour later the vessel breaches at high pressure. Containment sprays start and operate successfully. The debris in the cavity cannot be cooled, however, and its temperature reaches 2500K seven hours after shutdown. Five hours later the temperature is stabilized at 1600K. Large quantities of hydrogen and carbon monoxide were generated. Combustion occurs 43 hours after shutdown and causes the containment to fail. As a consequence, radionuclides escape to the environment.’

The release began 43 hours after the shutdown, at 08:00, and lasted for 12 hours. The release rate decreased roughly exponentially within 12 hours. The venting occurred at a height of 60 m, but the released plume rose to 100 m (effective release height) due to thermal buoyancy. It was assumed that the initial sensible heat release rate was in the order of a few megawatts.

The following weather situation was selected from the historical numerical weather prediction data. The accident day was a rainless day over Finland with weak winds (4–9 m/s) from south and southwest. The wind turned during the second night and started to blow from south and southeast. There were sporadic rain showers during the night and in the morning hours on the next day when the radioactive material was released. Thereafter the weather was dry again. Based on the measurements it was concluded that the fallout could be described by the release fractions given in Table I (p. 10).

Table I. Release used in consequence calculations.

Nuclide group	Release fraction
Noble gases	$8 \cdot 10^{-1}$
Iodine total	$1.1 \cdot 10^{-2}$
Alkaline-group (Cs, Rb)	$1 \cdot 10^{-2}$
Tellurium-group (Te, Se, Sb)	$1 \cdot 10^{-6}$
Alkaline earth-group (Sr, Ba)	$<1 \cdot 10^{-10}$
Ruthenium-group (Ru, Mo, Tc)	$<1 \cdot 10^{-10}$
Lanthanide-group (La, Nb, Zr, Cm, Ce, Nd, Pm, Sm, Eu, Pu,refr. Ox. Nb, Zr)	$<1 \cdot 10^{-10}$

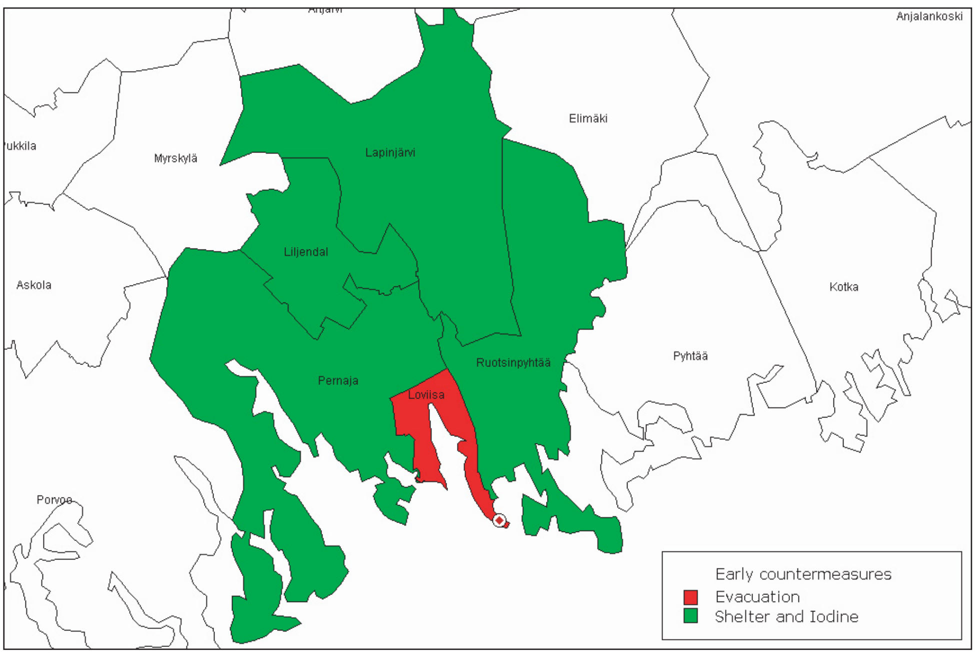


Figure 1. To protect the population evacuation, iodine prophylaxis and sheltering were recommended and implemented before the release had reached the marked municipalities.

2.2 Countermeasures recommended to general public

In a nuclear emergency situation numerous countermeasures are taken to protect the population, food chain, livelihood and environment. Precautionary countermeasures to protect the population were analysed prior to the workshop and discussed by emergency management experts. Since a core meltdown had occurred the experts recommended to *evacuate* the population of the town of Loviisa and of the eastern part of Pernaja on the accident day. In addition, the recommendations included *sheltering* during the passage of the plume and intake of stable *iodine* tablets prior to it in the following municipalities: Ruotsinpyhtää, Lapinjärvi, Liljendal and in the western part of Pernaja (Figure 1). This information was available at the outset of the workshop.

3 One week later

3.1 Clean-up techniques

It was assumed that the fallout composition and pattern had been roughly mapped (presumably via car and airborne gamma measurements) during the first week following the release and that numerous fallout samples had been analysed. It was concluded that the caesium and iodine fallout could be explained by a release of roughly one percent of the core inventory. Initially prevailing uncertainties were considerably lowered, but the dose assessments were still believed not to be more accurate than by a factor of 2 or 3.

The release contaminated various surfaces of the living environment. The extent to which a contaminated surface contributes to the dose depends on various factors: on the type and composition of the deposition, the time spent in the proximity of such surfaces and the shielding by building material. Assuming normal living conditions, the major contribution to the lifetime dose comes from the soil, about 60–80%, if the fallout contains caesium (Andersson 1996, Brown 1996, Moring and Markkula 1997). In urban downtown environments (office areas) the main contributors to the dose are walls and roofs, 30–60%. Under dry deposition situation the contribution of walls is about 5–10% and that of roads and pavements about 5%. Roofs contribute to about 10%. Because Finnish buildings are quite air-tight the lifetime dose from the indoor contamination is negligible if the ventilation is shut down during the plume passage.

There is a wide variety of clean-up techniques available for different surfaces. In developing decontamination strategies one has to know the distribution of the deposited material on different surfaces and the contribution that each surface adds up to the dose. Furthermore, one should consider the cost of a technique and its feasibility in terms of availability of the equipment and social acceptability. Also, the concern of people on their homes, by means of earning their living and the effects on the industry are important. The strategies to be considered were based on the selection of the surface to be cleaned up, on the choice of a clean-up technique and/or on the extent of the area to be cleaned up.

The aim of this study was to choose the most appropriate actions for cleaning up inhabited areas during summertime. The requirements for the actions were that they should be applicable on a large-scale and their early implementation is possible. Because of these constraints the equipment had to be readily available and preferably in common use. The following clean-up techniques were selected for further consideration. Table II (p. 15) gives the dose reduction factors estimated for this work (see also Andersson 1996; Moring and

Markkula 1997) and Table III (p. 15) contains the estimated costs of the selected clean-up techniques.

Buildings and streets

Buildings

In general, fire hosing of roofs and walls with tap water removes relatively little activity from building surfaces and has only a minor effect in terms of dose reduction. However, in some cases it can be considered, especially in dry deposition scenarios, shortly after the accident and for detached houses where the dose reduction has been assessed to be moderate. The efficiency of the method can be improved significantly by using a brush in order to remove also organic materials. High pressure water treatment (through a turbo nozzle) could also be used for decontamination of roofs and walls. These techniques have been found more efficient when done in the early phase after the deposition, presumably due to the time-dependent fixation of caesium ions in the structure of materials. Other methods, e.g., sandblasting and ion-exchange, are generally expensive.

A serious problem with hosing and high pressure water treatment is controlling the water and aerosols that could contaminate the soil around the buildings and thus increase the dose rate. The water has to be collected, contaminated soil removed and the waste disposed.

Streets

Wet sweeping or wet vacuum sweeping are suggested for the roads. If municipal road-cleaning machines (with rotating brushes and vacuum attachment) or mere mechanical rotating brooms on tractors are enough, it would be possible to sweep the streets much faster and therefore less expensively. In a series of experiments on a freshly contaminated road, the wet vacuum sweeping removed in some cases twice as much contaminants as sweeping with an ordinary broom (Andersson 1996). The efficiency of the method has been found to be greatly dependent on the amount of street dust per square meter.

Fire hosing of streets is assumed to be done with normal tap water or with a tanker lorry. In fire hosing water washes the contaminants away from the roads into the drainage system for rainwater. Dependent on construction of the drainage system the rainwater is either led into the purification system and mixed with the purified sewage or led directly into lakes or the sea. During sewage purification about half of the contamination remains in the sewage sludge and the other half will be released with the purified sewage (Puhakainen 2004) and will eventually end up in ditches, rivers, lakes and seas.

Removal of grass and foliage

Grass

As a decontamination measure, contaminated grass can be cut normally and safely deposited. Grass cutting should preferably be done with a cutter that has a collector attached. If a collector is not available, the cut grass has to be raked up. However, hand raking in large areas is not feasible. The cut grass is subsequently collected and buried at a controlled disposal site. If grass cutting is done within a few days after the dry deposition it is effective in reducing the dose. The transfer process of caesium contamination from grass to soil has been found to have a half-life of about 15 days. It is also a cheap method and because people can do it by themselves it will also relieve their anxiety.

Grass removal is most effective in a dry deposition situation and when done within two weeks after the fallout. After a few weeks it is useless. The method can also be considered in wet fallout situations.

Foliage

In addition to grass, trees and bushes are effective interceptors of airborne particles. By removing trees and bushes in the vicinity of buildings the dose will be reduced considerably, but only if done in the first years. It is assumed that branches of deciduous trees are cut off and conifer trees are felled. Leaves have to be collected and disposed of in the fall.

Pruning or felling of trees is effective in dry deposition situations and when done in the first month after the fallout. After the first year it is useless.

Soil

Turf removal

Since the downward migration of caesium is slow, scraping the topsoil will be effective for years after the fallout. Soil samples have shown that the fallout from the nuclear weapons test explosions in the sixties and from the Chernobyl accident can still be detected in the top 30 cm (Ilus 2004). Scraping of turf, about 5 cm, is assumed to be carried out using a spade in small scale, and a digger and a front loader in large areas. The problem with scraping of soil is the generation of large amounts of waste. If fertile soil or/and vegetation is removed the method should also include reconstruction of land and planting of vegetation.

Table II. Estimated dose reduction in percents of the effective lifetime dose (70 years) for the selected clean-up techniques in a case of dry and wet deposition of ^{137}Cs.

	Type of fallout	Roof washing	Wall washing	Street sweeping	Tree pruning	Grass cutting	Turf removal
Detached houses	dry	7	8	4	9	50	60
Wooden	wet	7	7	4	1	15	75
Detached houses	dry	10	4	4	10	45	58
Brick	wet	10	3	4	1	15	72
Row houses	dry	6	2	5	6	55	71
	wet	4	1	6	1	15	76
Blocks of flats	dry	1	3	7	4	59	74
	wet	1	2	15	0	15	77

Table III. Estimated monetary costs, waste generated and man power needed per unit of treated surface area by the selected clean-up techniques.

Clean-up action	Labour costs €/1 000 m^2	Disposal costs €/1 000 m^2	Waste kg/1 000 m^2	Working hours/1 000 m^2, per detached house
Street hosing	350	0	0	10
Street sweeping	15	1.6	100	0.3
Roof washing	750	16	10 000 water	33, 4 h/roof
Wall washing	200	16	10 000 water	11, 1.7 h/house
Grass cutting	75	0.8	10	3, 2.5 h/yard
Tree pruning	120	16	0.8	5.3, 4.3 h/ yard
Turf removal	400	800	75 000	24, 19 h/yard

Soil cover

Covering contaminated surfaces with clean soil, concrete or asphalt is most applicable in small scale. Covering the contamination with clean soil and scraping the topsoil are applicable independent of the type of fallout and the time since the accident.

Rotovating, digging or ploughing

In rotovating, the contamination is mixed within the upper 10–15 cm of soil but when using digging and ploughing methods the contamination is relocated somewhat deeper in soil. Digging could be considered in small scale and ploughing and rotovating in large urban areas, as in open parks. During deep-ploughing the soil is turned up to 45 cm whereas with an ordinary plough to about 25 cm. In digging and ploughing, there is no waste generated. An especially advantageous solution would be the application of a specially constructed skim and burial plough which has approximately the same dose-reducing effect as deep-ploughing but leaves the soil quality unaffected. The efficiency of these procedures will depend greatly on the soil type. In stony soil and areas having dense vegetation the methods are not feasible.

Consequence assessment of clean-up

There are methods which were considered not to be applicable when large areas have to be decontaminated and/or during the first weeks of the accident: peelable coatings, road planning, skim and burial ploughing and sand blasting. These techniques were rejected after a comparison with the above mentioned techniques due to their poor effectiveness, high costs or low feasibility.

If no recovery operations are taken, the contamination remains in the area. The dose rate will, however, decrease in the course of time through natural processes (radioactive decay, weathering, migration to deeper soil layers, wash off, resuspension) and human activities (dispersion by vehicle traffic, regular cleaning). Unfortunately, it appears no systematic studies of long-term weathering and the effect of human activities on dose reduction have been carried out.

The labour costs were estimated to be 25 €/hour including overheads. Digger, lorry, front loader and vacuum sweeping costs with a machinist were estimated to be 50 €/hour. The workers' dose, man-hour and the generated waste were based on the following assumptions:

- Roofs and walls are washed using a brush and hosed with tap water. Lift frames and lorries are available.

- Grass is cut predominately by residents using small lawn mowers equipped with collectors. The grass is put into refuse sacks, the collection of which, as well as the waste disposal, are organised by the local officers
- Trees and bushes are pruned or cut mainly by light machinery, collected, chipped and disposed of. The work is organised by the local officers in cooperation with the local residents.
- Streets are vacuum swept by equipment locally available. Dust and sand are collected by lorries and disposed of preferably in surface trenches together with other waste.
- Scraping of the turf (5 cm) is done by a digger and assisted by a front loader and a lorry. It is assumed that the removed soil is replaced and the yards replanted.

In order to assess the dose, costs and total amount of waste of the various clean-up actions, information was needed on the actual size of the treated surfaces and on the population distribution. The actual size of the treated areas was calculated by multiplying the estimated size of the treated surfaces per house type (Table IV) with the number of house type per a square kilometre (Statistics Finland). This figure was multiplied with the estimated costs and waste per unit of the treated surface area (Table III, p. 15). The avertable collective dose of a particular clean-up action was calculated by multiplying the number of persons of each square kilometre living in a given house type (Central Statistical Office of Finland 1996) with the dose estimate for the relevant house type and square kilometre.

Table IV. Size of the surface areas per house type that is assumed to be treated by clean-up actions.

House type	Roof m^2	Walls m^2	Streets m^2	Yard[1)] m^2
Detached houses	120	150	400	600
Row houses	300	400	700	600
Blocks of flats	450	1 000	1 000	2 000
Other type	120	150	500	600

[1)] If parks in the area are also in the treated yard, the area should be increased by 100 – 200 m^2.

Disposal of generated waste

Grass, undervegetation, litter, humus and soil have to be disposed of as such. Wood material can also be disposed of as it is, but chipping trees, branches and stumps will help the disposal and rotting of material. In all cases, the final disposal cannot be undertaken before the organic material is rotten.

Studies of clean-up strategies in forest environments indicate that burning of wood before disposal is an attractive alternative both to reduce the amount of waste and to gain some monetary benefit (Lehto 1994). There are small (5 MW) and large (20–200 MW) power stations suitable for burning chipped wood material in Finland. If proper electrostatic precipitators are used, 95–99% of radionuclides will remain in the ash. The amount of waste ash to be disposed of would be small. However, there will remain some concern, especially among the population living in the vicinity of the power stations, when burning radioactive material.

Disposing of the ash of the burned wood and cut grass (after rotting) from highly contaminated areas will cause high individual doses to the workers. Since tens of mSv can be expected, special working arrangements are needed.

3.2 Fallout area and consequence assessments

The site of the hypothetical accident is situated 90 km east from the capital area of Finland and 10 km southeast from Loviisa town. There are 7600 inhabitants in Loviisa and over one million inhabitants in the whole fallout area (Table V, Figure 2).

There was rain in Loviisa, Liljendal, Lapinjärvi, Pernaja and Ruotsinpyhtää during the plume passage, which caused wet deposition in parts of these municipalities (over 50 kBq/m^2). Close to the nuclear power plant the measured fallout was over 5 000 kBq/m^2. Elsewhere up to Mäntsälä the fallout was 5–50 kBq/m^2 and a decade lower in the capital area of Finland.

The ^{134}Cs fallout was equal in magnitude to the one from ^{137}Cs, and the deposition of ^{131}I was ten times higher. In this scenario the lifetime dose is mainly caused by caesium isotopes and only a few percents are caused by iodine. The dose rate was high during the first week after the accident as a result of the iodine fallout. This had to be taken into account when planning clean-up actions.

A dynamic compartment model had been developed earlier at STUK to assess the transfer of caesium within the urban environment and to calculate the dose savings for the selected decontamination techniques (Moring and Markkula 1997). In this model, the Finnish house types and living habits were taken into account and matched the house type statistics from Statistics Finland.

Table V. Municipalities in the fallout area and the number of inhabitants.

Artjärvi	1 570	Kerava	30 482	Pernaja	3 783
Askola	4 421	Kärkölä	4 978	Pornainen	4 186
Espoo	216 836	Lapinjärvi	2 995	Porvoo	45 403
Hausjärvi	8 173	Liljendal	1 464	Pukkila	1 936
Helsinki	559 718	Loviisa	7 498	Riihimäki	26 268
Hyvinkää	42 736	Myrskylä	1 974	Ruotsinpyhtää	2 967
Iitti	7 415	Mäntsälä	16 908	Sipoo	17 760
Järvenpää	36 380	Nurmijärvi	34 029	Tuusula	32 915
Kauniainen	8 543	Orimattila	14 202	Vantaa	179 856

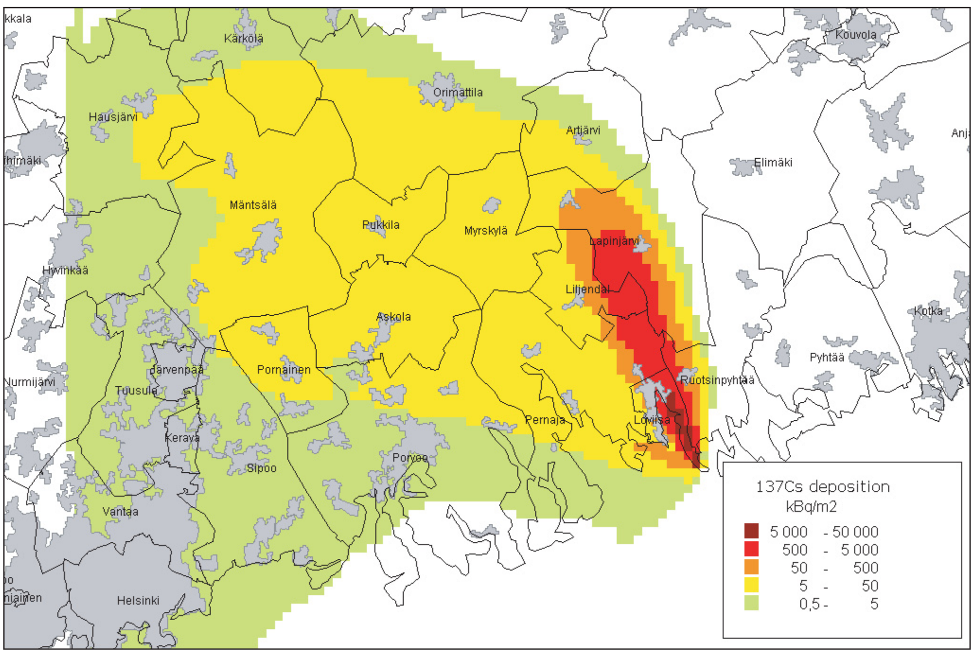


Figure 2. The caesium deposition, affected municipalities and population centres (grey areas).

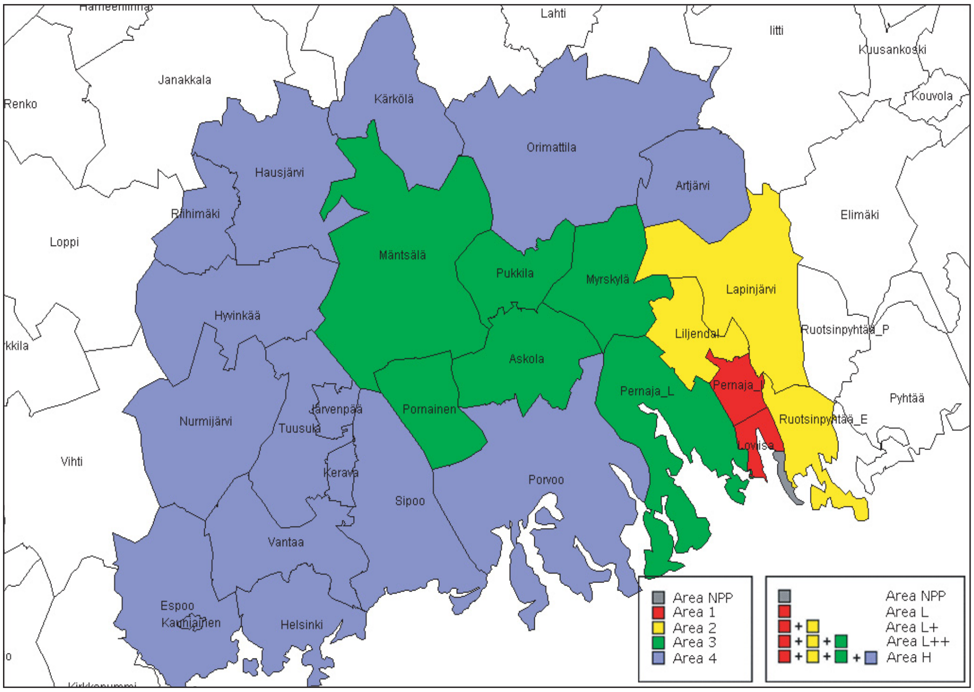


Figure 3. Subdivision of the fallout area for consequence assessment.

Table VI. Key figures for the 5 areas and the consequence assessment if no actions are taken.

	Area NPP	Area 1	Area 2	Area 3	Area 4
Number of population	28	8 429	6 070	29 600	1 101 614
Number of houses	25	2 191	2 487	10 845	14 4025
^{137}Cs fallout (kBq/m^2)	7 423	1 145	273	8	2
Dose in days 1–7 (mSv)	19	3	1	0	0
Dose in days 7–30 (mSv)	36	5	1	0	0
Dose in days 7–365 (mSv)	287	44	11	0	0
70-year dose (mSv)	2 263	213	73	2	0
Collective dose, 70 y (manSv)	63	1 797	440	67	283
Increased cancer cases	6	180	44	7	28

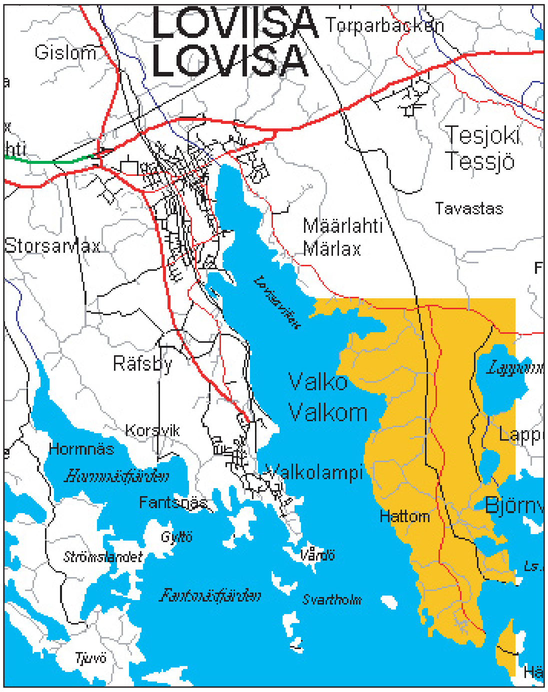


Figure 4. Loviisa town and the Area NPP (marked with ochre).

The fallout pattern of iodine and caesium isotopes, the dose rate and the doses received within the first week were calculated by the RODOS system (Ehrhardt and Weis 2000). In this work script and spreadsheet softwares were developed to calculate the collective doses, workers' dose, volumes of waste generated and the monetary costs of actions for various possible action strategies.

For the purpose of the analysis of the clean-up recommendations, the major fallout area was subdivided into 5 areas (Area NPP and Areas 1 to 4 in Figure 3) according to the caesium fallout but taking into account the demographic and administrative features. With the exception of the municipalities of Loviisa, Pernaja and Ruotsinpyhtää (which were divided such that the dividing line passed through sparsely populated areas), the subdivision was made along the municipality borders. Table VI gives an assessment of the consequence within these areas if no clean-up actions are performed.

Area NPP is the most contaminated area but it has only 28 inhabitants (Figure 4). The ^{137}Cs fallout was more than 5 000 kBq/m^2 in that area and the dose rate caused by the fallout was 0.6 mSv/h in the first hours after the plume passage. The estimated 70-year dose is over 2 000 mSv.

Area 1 consists of Loviisa town and the eastern part of the municipality of Pernaja. The average ^{137}Cs fallout was 1 000 kBq/m^2 in that area. The NPP and Loviisa were evacuated prior to the release and the inhabitants of Pernaja were recommended to take iodine tablets and to shelter indoors during the plume passage. If the inhabitants of Loviisa returned to their homes one week after their evacuation they would receive a dose of 5 mSv by the end of June and 213 mSv in 70 years. These figures might be put into perspective by comparing them to the dose that the inhabitants of that area receive from the inhalation of radon, which is estimated to be 7 mSv in one year and 500 mSv in 70 years.

Area 2 encompasses Liljendal, Lapinjärvi and the southern part of Ruotsinpyhtää. The fallout was very uneven in these municipalities and the estimated population weighted average was 270 kBq/m^2. The inhabitants were recommended to take iodine tablets and to shelter indoors during the plume passage.

There was no rain in other areas during the plume passage and the ^{137}Cs fallout ranged between 5 and 50 kBq/m^2 in Area 3 and between 0.5 and 5 in Area 4.

An avertable effective dose of 50 mSv in a week is used as the planning criteria for evacuation in Finland. Permanent resettlement of the population is recommended if the avertable lifetime dose is 1000 mSv (IAEA 1994, ICRP 1993). On the grounds of these intervention levels permanent resettlement in Area NPP is justified and continuing the evacuation of Loviisa town for one or three weeks could be considered due to the high iodine fallout. These were, in addition to clean-up actions, the alternatives that the participants of the workshop could choose from.

Tables VII–XII give an assessment of the tangible consequences of the feasible actions within each area. A wide range of strategies can be defined and assessed by using the information given in these tables. For example, the evacuation of the population in Area 1 could be prolonged for another week, the roofs and walls of their houses could be cleaned, the contaminated grass removed from their yards and some trees felled in front of their houses; similar clean-up actions could be implemented in Area 2, and grass cutting and street cleaning in Areas 3 and 4. An assessment of the consequences of such a strategy is easily made with the data of Tables VII–XII.

The workers' dose was estimated by considering the time in which each action should be completed. It was assumed that sweeping of streets, washing of houses and cutting of grass should and could be done in one week, pruning of the vegetation in two weeks and scraping the topsoil in three weeks. In addition to the dose caused by the clean-up action itself, i.e., the dose received outdoors, the dose caused by transportation and waste disposal was roughly estimated by using

Table VII. Consequence assessment for permanent resettlement of the population of Area NPP.

	Permanent resettlement
Average avertable dose (mSv)	2 260
Avertable collective dose (manSv)	63
Avertable number of cancer cases	6
Costs (M €)	400

Table VIII. Consequence assessment for evacuation and permanent resettlement of the population of Area 1.

	Evacuation days 7–14	Evacuation days 7–30	Permanent resettlement
Average avertable dose (mSv)	2	5	210
Avertable collective dose manSv)	17	46	1 800
Avertable number of cancer cases	2	5	180
Costs (M €)	5.5	16	5 100

Table IX. Consequence assessment of clean-up actions in Area 1.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	11	10	8	27	2	120
Avertable collective dose (manSv)	90	84	70	230	17	1 030
Avertable number of cancer cases	9	8	7	23	2	103
Costs (M €),	0.2	0.1	0.0	0.1	0.2	1.7
Worker dose (manSv)	0	0	0	0	0	1
Waste (1 000 kg)	3 080	4 300	96	14	1	108 000
Working days	1 300	590	36	540	960	4 300

Table X. Consequence assessment of clean-up actions in Area 2.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	4	4	2	9	1	42
Avertable collective dose (manSv)	24	23	14	56	4	250
Avertable number of cancer cases	2	2	1	6	0	25
Costs (M €),	0.2	0.1	0	0.1	0.2	1.8
Worker dose (manSv)	0	0	0	0	0	0
Waste (1 000 kg)	3 200	4 000	103	15	1	113 000
Working days	1 300	550	39	560	990	4 500

Table XI. Consequence assessment of clean-up actions in Area 3.

	Washing roofs	Washing walls	Vacuum sweeping streets	Grass cutting	Pruning vegetat.	Scraping topsoil
Average avertable dose (mSv)	0	0	0	1	0	1
Avertable collective dose (manSv)	4	4	2	23	4	32
Avertable number of cancer cases	0	0	0	0	0	3
Costs (M €),	1.1	0.4	0.1	0.5	0.9	8
Worker dose (manSv)	0	0	0	0	0	0
Waste (1 000 kg)	13 900	17 800	450	66	5	497 000
Working days	5 700	2 450	168	2 490	4 400	19 900

Table XII. Consequence assessment of clean-up actions in Area 4.

	Vacuum sweeping streets	Grass cutting
Average avertable dose (mSv)	0	0
Avertable collective dose (manSv)	10	110
Avertable number of cancer cases	1	11
Costs (M €)	1.2	8.1
Worker dose (manSv)	0	0
Waste (1 000 kg)	7 000	1 070
Working days	2 600	40 000

the MATERIA and MicroShield softwares (Markkanen 1995; MicroShield 1996). Certain work stages, such as driving a full load in a machinery and especially disposing onto an open waste trench, might cause doses which exceed the dose limits for workers. For example, it was estimated that the ^{137}Cs activity in 1 m^3 of vacuum swept waste was 10 000 000 kBq and it alone caused the dose of 0.1–0.2 mSv in an hour and 1–2 mSv in a day to a driver of machinery in the town of Loviisa.

The evacuation and permanent resettlement costs were assessed applying methods presented in the COCO model (Haywood et al. 1991) and the RODOS system (Hasemann 2000).

The intervention measures entail also non-radiological risks to the population and the workers caused by various kinds of accidents, for example, during washing roofs, cutting grass and felling down trees. The risks that are directly associated with remedial actions were estimated using Finnish statistics (Central Statistical Office of Finland 2003). The Statistical Yearbook, however, does not directly give the accident statistic for clean-up actions considered here and therefore the risk was estimated using accident risks in transportation, construction and forestry. The accident rate was not significant; if all the clean-up actions are taken in Loviisa town, one statistical accident might happen. However, if houses are washed in the Helsinki metropolitan area, circa 20 accidents might happen.

Before the workshop eight tentative strategies were defined and their tangible attributes assessed. The strategies were presented as combinations of different countermeasures to show in detail the different actions in each strategy and also to show the participants how new strategies could be defined during the workshop (Tables XIII–XIV, p. 26).

Table XIII. The tentative definition of strategies (see also colour codes in Figure 3, p. 20).

Clean-up action	Strategy							
	max	A	B	C	D	E	min	0
Permanent resettlement	L							
Evacuation, days 7 – 30		L	L	L	L			
Evacuation, days 7 – 14						L		
Washing of houses	L++	L++	L++	L+	L	L		
Sweeping of streets	H	H	H	L++	L+	L	L	
Pruning of vegetation	L++	L++	L++	L+	L	L		
Cutting grass	H	H	L++	L++	L+	L	L	
Scraping of topsoil	L++	L+	L+	L	L			

L comprise Loviisa and eastern part of Pernaja;
L+ comprise in addition to **L**: Liljendal, Lapinjärvi and southern part of Ruotsinpyhtää;
L++ comprise in addition to **L+**: western part of Pernaja, Myrskylä, Askola, Pukkila, Pornainen and Mäntsälä;
H comprise in addition to **L++**: Artjärvi, Orimattila, Kärkölä, Hausjärvi, Riihimäki, Hyvinkää, Porvoo, Sipoo, Järvenpää, Kerava, Tuusula, Nurmijärvi, Vantaa, Espoo, Kauniainen and Helsinki.

Notes:

- Area NPP will be resettled in every strategy
- Grass will not be cut in areas where surface soil will be scraped
- In Strategy max no cleaning actions will be carried out in area L

Table XIV. The health consequences and costs of the strategies.

Attributes	Strategy							
	max	A	B	C	D	E	min	0
Cancer incidents	36	83	94	114	120	210	231	261
Saved cancer incidents	225	178	167	147	141	51	30	0
Costs of clean-up actions (M €)	22	17	9	4	2	1	0	0
Costs of relocation (M €)	5 100	16	16	16	16	6	0	0
Overall costs (M €)	5 122	33	25	20	19	6	0	0

Note. The actions taken during the first week are not included in the numbers.

4 Workshop on clean-up actions

4.1 Workshop arrangements

The facilitated workshop was assumed to be organised a week after the accident. Prior to the workshop many personal contacts were made in order to build up a group of key players and to collect local background information. It was seen important that also persons living in the contaminated area were present in the workshop. Therefore, people who due to their occupation had a role in performing clean-up actions and who also lived in Loviisa town were invited. The following list shows the organisations which were considered to be necessary for the decision making process and the number of their representatives:

- Ministry of Social Affairs and Health, one participant
- Ministry of Interior, one participant
- County Administrative Board of Southern Finland, Rescue Office, one participant
- Town of Loviisa, Rescue Office, one participant
- Town of Loviisa, Technical Office, three participants
- Federation of municipalities of Loviisa region, one participant
- Employment and Economic Development Centre for Uusimaa, one participant
- Environment Agency of Uusimaa, two participants
- Radiation and Nuclear Safety Authority, STUK, two participants.

The workshop was facilitated by Prof. Raimo P. Hämäläinen, Helsinki University of Technology (HUT), and assisted by three technical analysts from HUT. STUK provided a secretary and two persons who assisted the workshop on radiological and other technical issues. A representative from the EVATECH project was also present.

A portable decision support system was used to support the decision analysis in the workshop. It consisted of seven portable notebooks, a wireless local area network, projectors and the Web-based multicriteria decision analytical software called Web–HIPRE[1] (Mustajoki and Hämäläinen 2000, Mustajoki et al. 2004) (Figure 5, p. 28). Web-HIPRE was used for the decision modelling and analysing the results. It provided a multi-attribute value theory (MAVT) -based approach for modelling the preferences of individual decision makers. It also provided a way to aggregate individual models into a group model, an aspect

[1] http://www.hipre.hut.fi

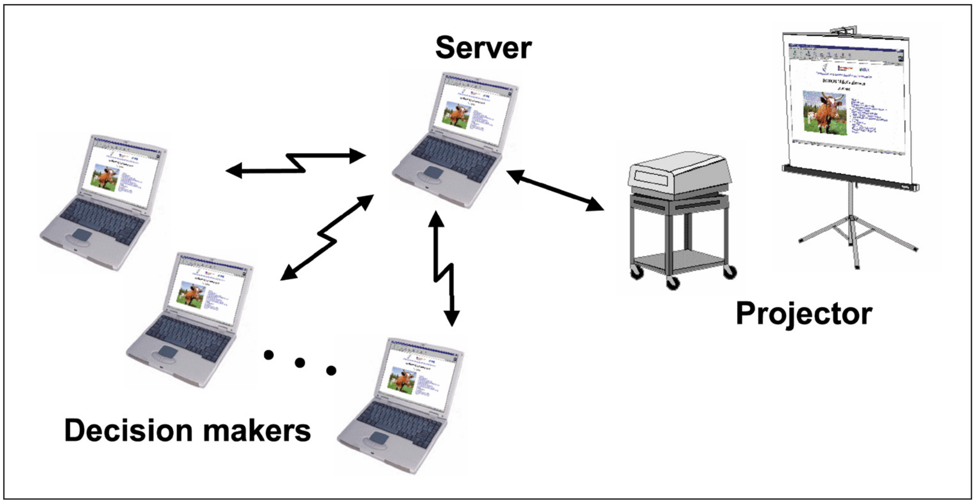


Figure 5. The technical arrangements.

that made it specially suitable for the workshop, as it made it possible to collect and combine the results of individual groups.

Before the workshop, all the participants received an information package containing a description of the accident scenario, potential clean-up techniques, and consequence assessments for tentative strategies. In addition, information was provided on the tasks of the participants in nuclear emergency management and on risk perspectives in different radiation exposure situations. At the beginning of the workshop, the facilitator gave an overview of the facilitated workshop method, and of the main features and steps of the decision analysis. A radiation protection expert briefed about the accident, the consequences of the clean-up techniques and their effectiveness. At the end of the introduction phase, the health risks due to radiation exposure from this hypothetical accident were compared with other exposure situations to get a view of the severity of the accident. The presentations took about one hour.

The participants formed six groups. Each group was equipped with a notebook computer that allowed them to interact directly with Web-HIPRE. Except for two, the participants had no earlier experience in decision workshops or decision support, which placed high demands on the usability of the system.

The workshop lasted for seven hours, which seemed to be convenient for participation. At any rate, it would have been difficult for the participants to allocate more time than this. As in a real situation, the time frame was so tight that preparatory meetings were needed to prepare the materials and develop tentative strategies.

4.2 Attributes relevant for the analysis

The facilitator started the decision analysis by presenting the tentative strategies to protect the population and showed their consequences (Tables XIII and XIV, p. 26). Then he led the participants to discuss the issues and concerns they had when considering the protective actions included. During the discussion key words and their definitions were written down and projected on the screen to be reviewed by everybody. This brainstorming took about one hour.

Communication with the public and the media was considered a crucial issue. The risk perceived, in addition to health effects, can have serious economical and social consequences, e.g., to the industry. Public opinion and perceptions of risk could result in consequences which may reduce the benefits of the actions, make their implementation impossible or even lead to too excessive actions. For example, the people (and the industry) might not accept any products from the contaminated area although the contamination would be removed very efficiently. The industry might think that the risk of being discredited by using contaminated materials is too great, and thus refuse to use even slightly contaminated raw materials. Nevertheless, it was concluded that whether the communication succeeded or not it does not depend on the strategies.

Psychological stress could lead to health effects of a comparable nature to those arising from the contamination and, at the same time, reduce the quality of life significantly. A majority of the inhabitants in a contaminated area may show varying degrees of stress reactions in response to the accident, but stress could also be a consequence of a protective action. The accident will be comprehended and evaluated also through the protective measures and it will be felt more severe if aggressive measures, e.g., removing soil and trees in the gardens, are taken. Appropriate actions, however, will offer reassurance to the population that it is safe to live in the affected area. Especially measures that people could implement by themselves are the most effective in reducing stress. Because people will be concerned and stressed about living in a contaminated area, actions that do not directly relate to radiological actions (for example counselling and psychological support in the crisis) are needed to reduce the psychological effects of an accident.

Protective actions would cause monetary costs to individual house and land owners, the industry and the society. The costs would include transportation costs, loss of income, costs of guarding the area and costs of lost capital services. Also, the question of reimbursing individual owners for any protective actions was raised. If any compensation is paid, either in full or in part, it would mean that the costs to individuals would now be costs to the society. Nuclear Acts, the Radiation Safety Act and Nuclear Liability Acts aim to cover all nuclear accidents in Finland.

The clean-up actions are dependent on the decision how the waste generated would be treated. According to the Finnish Law, it is possible to bury the radioactive waste, but it will be difficult to do so in practice. For example, the town of Loviisa does not have its own dumping place but the general procedures for clean-up actions imply that the generated waste is to be buried in the contaminated area (Lehto 1994). It is expected that every burial site would be objected to by various stakeholders.

The recommendations of international organisations (ICRP 1991, 1993, 2000; IAEA 1994, 1996; OECD/NEA 1990) are not based on the application of dose limits or any predetermined limits for deciding on the intervention. However, the position of workers carrying out recovery operations is different. These actions, albeit in response to an accident, can be planned and optimized in advance, and therefore it is recommended that workers undertaking recovery operations should be subject to the normal radiation protection system and the related dose limits should be followed. The workers should carry personal individual dose meters. It was concluded that by careful planning of the work, education and dose control the workers' dose could be restricted to a few mSv.

Finally, all the relevant issues were grouped into different categories (Table XV) which formed the basis for the value tree. The key words were examined for suitability to measure the performance of the tentative strategies, readjusted and gradually the value tree of Figure 6 (p. 32) was agreed upon by the group. The strategy 'max', which meant the permanent resettlement of the population of Loviisa (see Table XIII, p. 26), was rejected for several reasons: it was considered overly excessive and would cause serious anxiety, some citizens would most likely be unwilling to move, and it would be difficult to define the limits of the evacuation area. It would also cause undesirable effects on the country's international reputation. Moreover, it is extremely expensive to organize the permanent resettlement of large population groups.

4.3 Analysis of the problem

Seven selected intervention strategies (all the strategies except the Strategy 'max' in Table XIII, p. 26) were accepted as a working hypothesis for the decision analysis. For these strategies the values of the 'hard' attributes, i.e., the costs and health effects, were calculated in advance (Table XIV, p. 26). The degree of performance of each strategy with respect to these attributes was encoded by a linear value function. This meant, for example, that one cancer case was effectively perceived to be as great a loss to the society independent of how many cancer cases are expected.

Table XV. Development and definition of the attributes.

Overall goal: Healthy residential environment

Health

Deterministic radiation related health effects: None

Occupational accidents: Some, but not a significant issue. Very few new traffic accidents.

Other Accidents: Some minor accidents.

Cancer incidents: Calculated over 70 years. Cancer incidents will be compared with those caused by radon entering houses from the ground. During the same period in Loviisa such cases are circa 100.

Immediate mental disturbances: Crisis support and counselling will be organized and available. General concerns will be considered under the socio-psychological attribute below.

Socio-psychological

Communication/Media: Active communication is vitally important and should be paid high attention. Can fail in the early hours but also in a later phase.

Reassurance: Also international aspects will be taken into account in this attribute as well as the following main issues:

- Credibility of countermeasures
- Credibility of the authorities

Anxiety of the population: The effects of too excessive actions will also be considered.

Environment

Residential environment: Quality of life and living after clean-up actions.

Surroundings: Restrictions in the consumption of game, wild mushrooms and berries.

Nature: Clean-up actions will lower the contamination left in the nature.

Water pathways: Contamination flowing into the sea will be diluted into an insignificant level of radioactivity.

Drinking water resources: Can be protected and taken care of. Contaminated waste will be located away from groundwater supplies.

Time span: Vegetation will regenerate.

Economy

Foreign trade: Credibility of the safety of products. Can it be influenced by countermeasures?

Continuation of industries and employment: Income losses will be compensated.

International reputation

Lost value of assets and properties: If firms go out of business it will be compensated, no compensation in the case of spontaneous relocation.

Age distribution in Loviisa: A high proportion is retired people.

Spontaneous relocation of population: Could take place in the beginning.

Direct clean-up costs: A nuclear accident fund is available following international conventions. It will cover all the clean-up actions.

Technical issues

Technical feasibility: If cleaning actions are planned well they can all be accomplished.

Adequacy of labour force: The number of workers needed is not high (less than a thousand, recruitment of labour can be managed by an adequate compensation level, industrial safety legislation remains in effect, dose control for workers.

Availability of cleaning and other equipment: Not a problem.

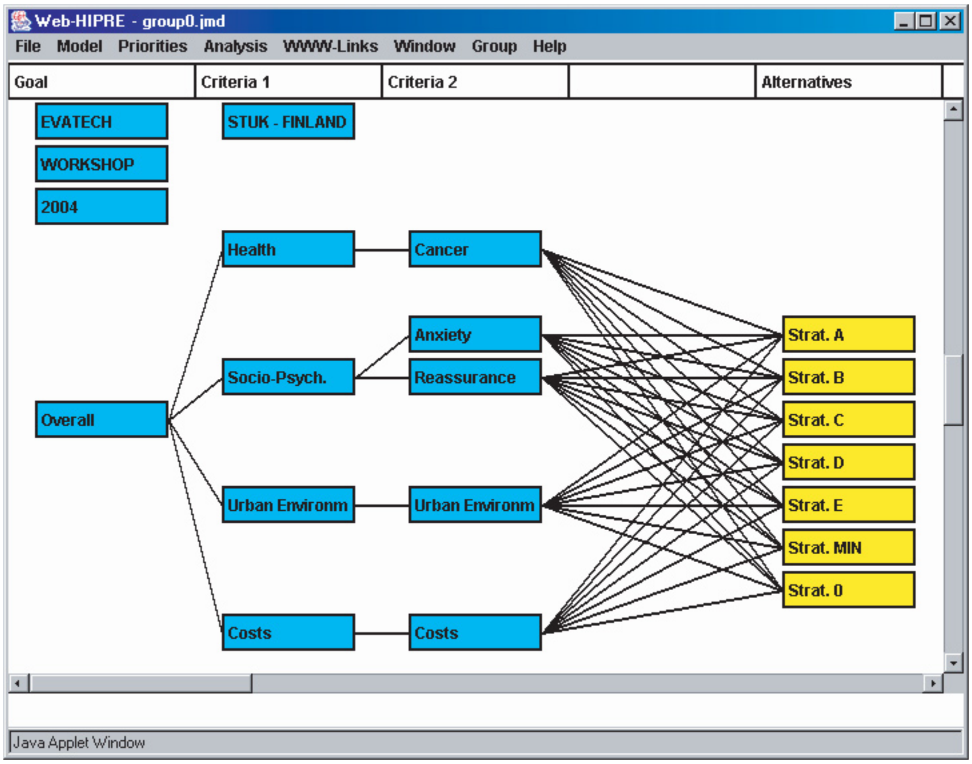


Figure 6. The value tree developed and used in the analysis.

The 'soft' attributes, such as intactness of the urban environment and anxiety, were directly rated by each group. In the technique used, the most preferred strategy with respect to each attribute was given a score of one and the least preferred strategy a score of zero. The other strategies were given scores between zero and one, according to their performance level. It was noted that the decimal number could be interpreted as a percentage of the maximum value.

In order to make the scores between the attributes commensurable with each other, the attributes were weighted according to their importance. This was done by each group separately with the Web-HIPRE software. In problem situations analysts familiar with the software provided assistance. The weights represented the relative importance that each group gave to the attributes with respect to their ranges. The result was a preference model of each group.

The Swing method (von Winterfeldt and Edwards, 1986) was used to elicit the weights of the attributes. In this method all the attributes were initially at their lowest preference levels and the participants were asked, if just one of the attributes could be moved to its best level, which one they would choose. This

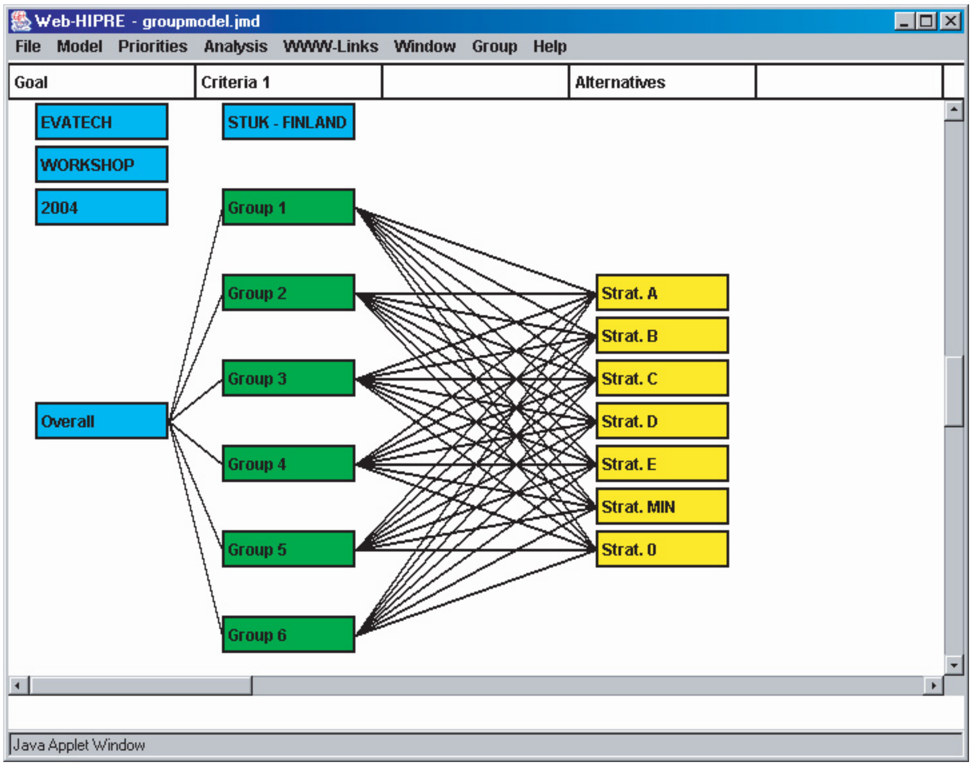


Figure 7. The group model.

attribute was given 100 points. After this change, the participants were asked which attribute they would next preferably choose to be moved to its best level, and so on until all the attributes had been ranked. These other attributes were given points reflecting the relative importance of their swings from the lowest to the highest level compared to the corresponding swing in the first ranked attribute. The facilitator stressed the participants to consider the attribute ranges when assessing the weights. The actual weights of the attributes were obtained by normalizing the sum of the given points to one.

Finally, the decision makers' preferences over the strategies were incorporated into the overall values of the strategies. These were derived with an additive model, i.e., by summing up the weighted scores of the attributes. As a result, each group got overall values for the strategies that reflected their preference judgements. The individual models were saved on the server and the results were projected on the screen and analyzed collectively one by one. The individual models were also aggregated into a group model, in which each element on the criteria level described the corresponding group (Figure 7). The scores for these elements were the group's individual overall values for each strategy. The overall group values for the strategies were obtained as a weighted sum of the overall values of each group so that each group element was equally weighted.

4.4 Results

The overall values of the strategies and some examples of sensitivity analyses that were carried out collaboratively in the workshop are shown in Figures 8.1–8.6 (p. 35–40). The overall values are divided into segments according the impacts of the different attributes to the overall values. The sensitivity analyses indicate the changes in the overall values of the alternatives when adjusting the weight of an attribute. These figures also show what factors are important and affected in the ranking. For example, it can be seen that costs were not decisive for any group but the ranking resulted due to other attributes. Only one group (group 5) assigned a bit higher weight to the costs. Although each interest group carried out value judgement independently, the resulting rankings had some aspects in common. Strategies 0, i.e. doing nothing, and min scored low within all groups. Any other strategy offered considerably better dose savings. Strategy E was also ranked low because of weak dose savings and low benefit of socio-psychological factors. Strategies A, B, C and D were ranked the best at least by one group.

As mentioned earlier, all the models were aggregated into a group model (Figure 9, p. 41). The aggregated group values are evenly weighted average overall values of the groups. The segments show the impact that the groups have on the overall value. This model also reflects the predominant preference for strategies A, B, C and D.

The strategy C was ranked the best in the group model. It was taken as a basis for a new strategy C* to further improve the performance of the clean-up actions with the insight gained during the analysis (Table XVI, p. 42). In this strategy, the evacuation was not seen to be strict but the house owners (however not children) could enter the area and guide and participate in the clean-up actions. Vacuum sweeping would be done in any case in the whole fallout area (H). Residents could be urged to cut the grass in their yards. The contaminated grass would be collected and disposed of by the municipalities. Because scraping of the topsoil is, compared to grass removal, much more effective in reducing the dose in a wet deposition situation, it was recommended to be done in the whole rain area. The consequences were calculated during the workshop (Table XVII, p. 42).

Rating of intangible attributes and attribute weights were discussed within the group and the model was recalculated with the new strategy C*. An example of the ranking of the strategies for group 1 is shown in Figure 10 (p. 41).

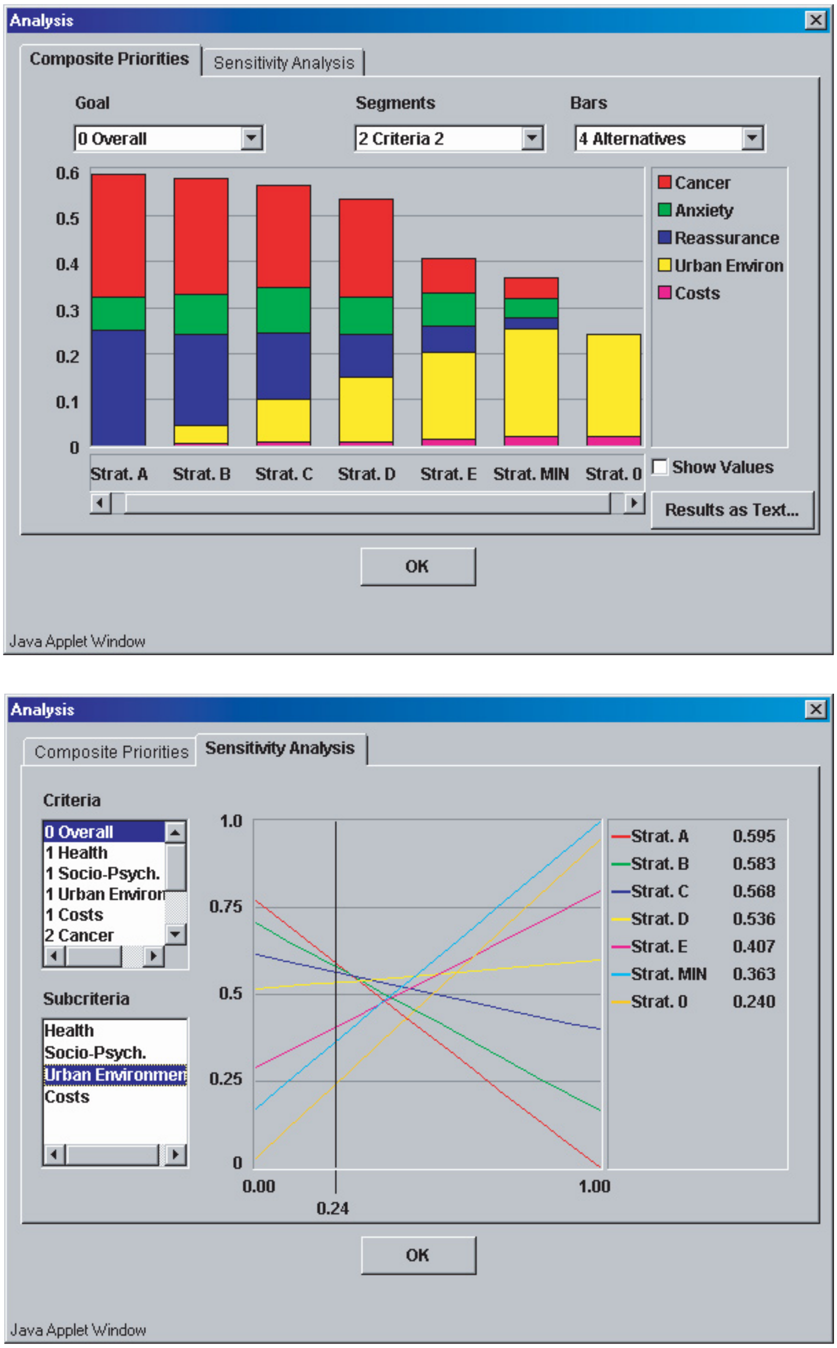


Figure 8.1. Evaluation of strategies by group 1: Overall values and Sensitivity analysis on Urban Environment.

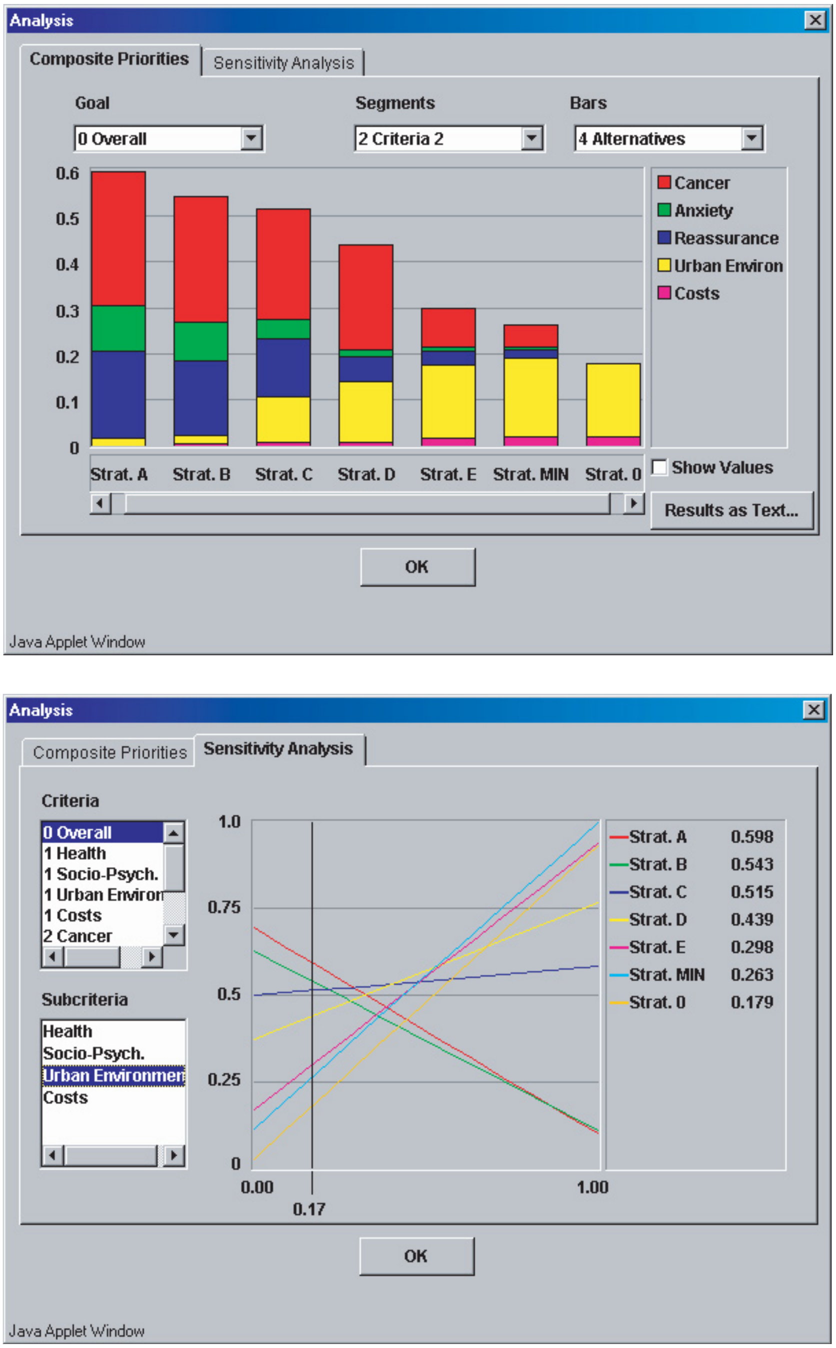
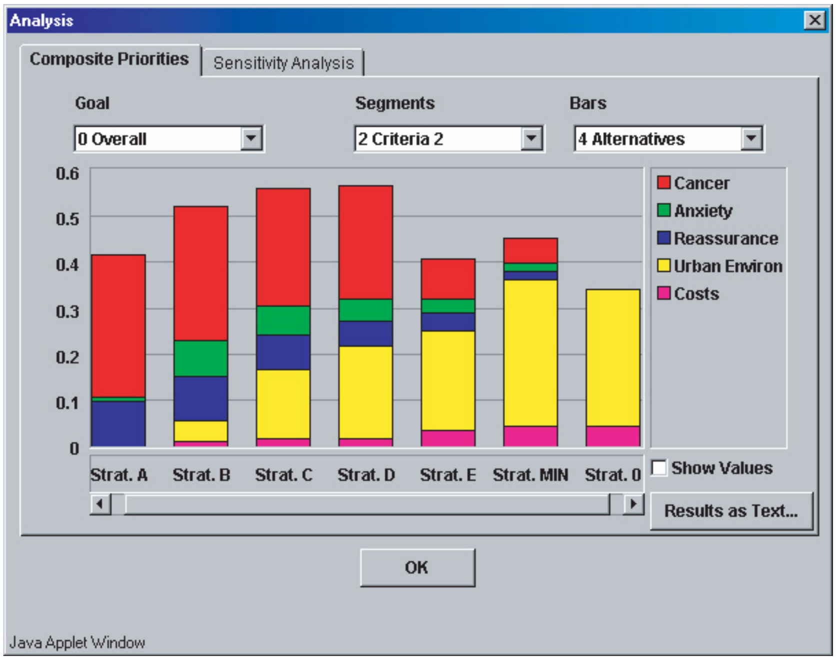


Figure 8.2. Evaluation of strategies by group 2: Overall values and Sensitivity analysis on Urban Environment.



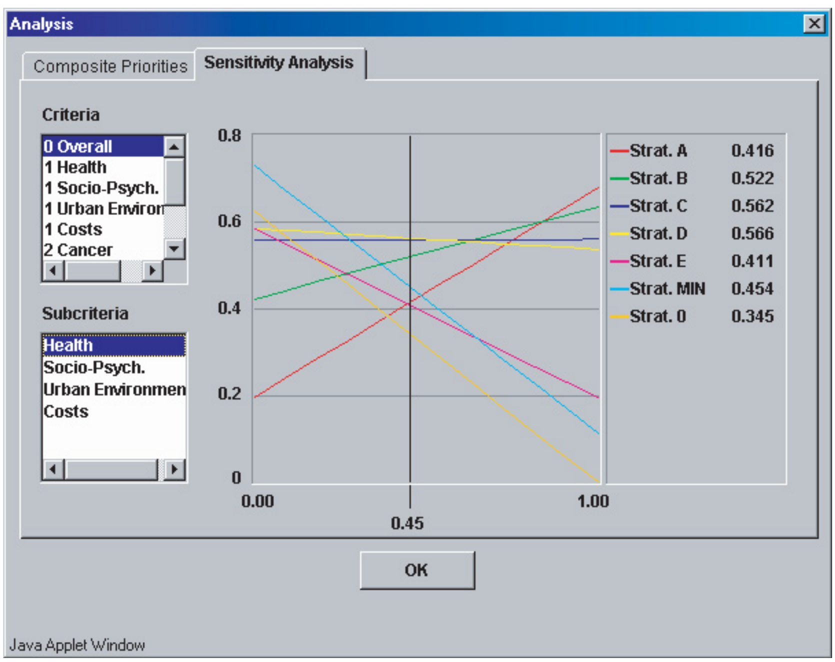


Figure 8.3. Evaluation of strategies by group 3: overall values and sensitivity analysis on Health.

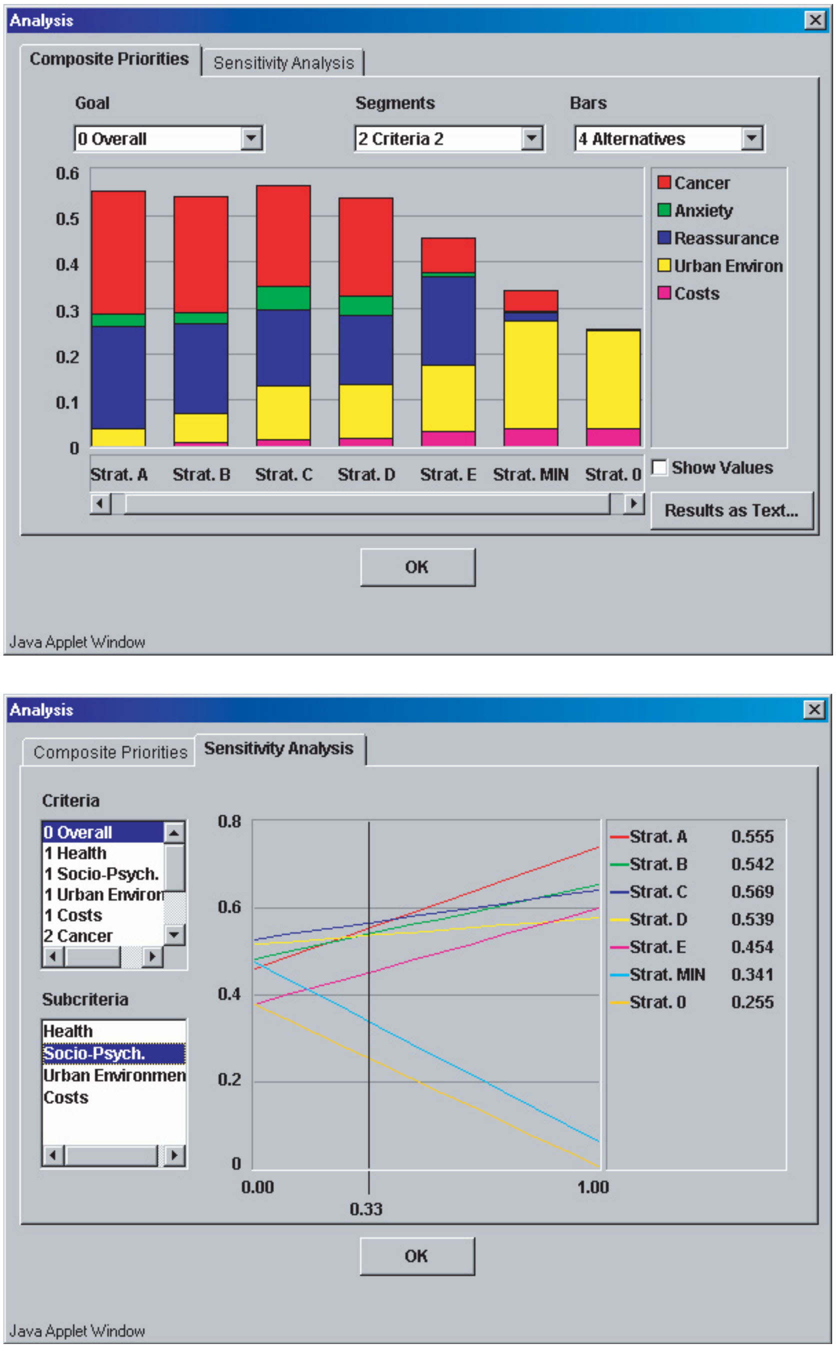
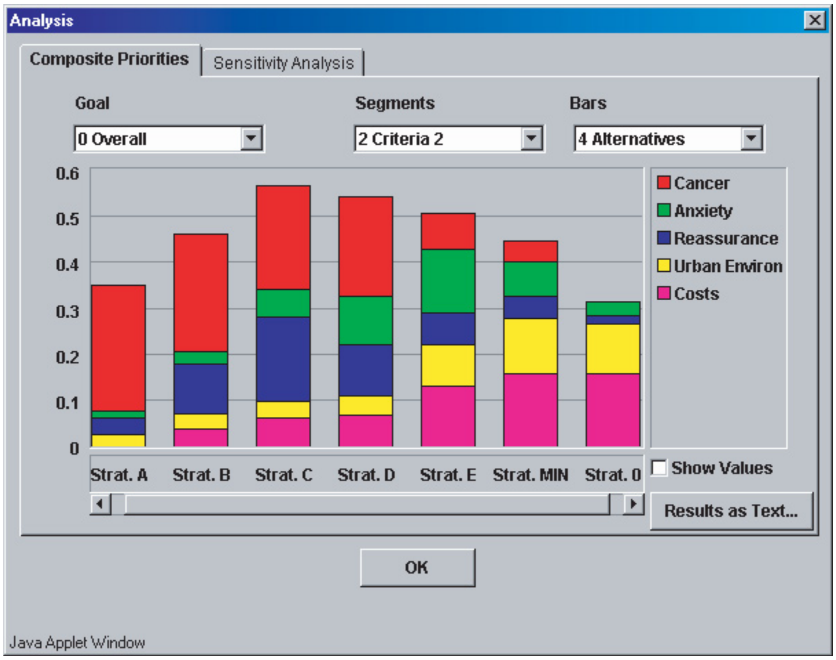


Figure 8.4. Evaluation of strategies by group 4: overall values and sensitivity analysis on Socio-Psychological.



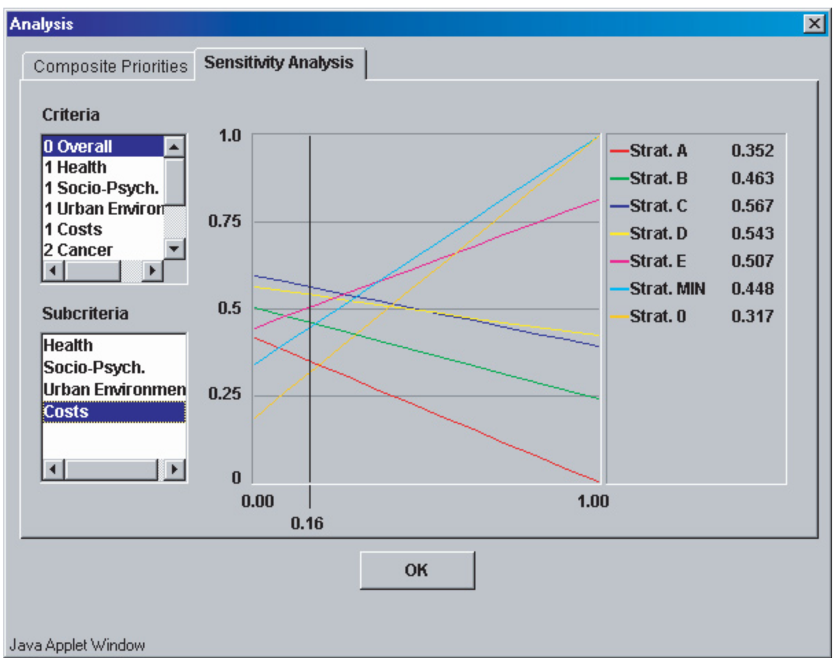
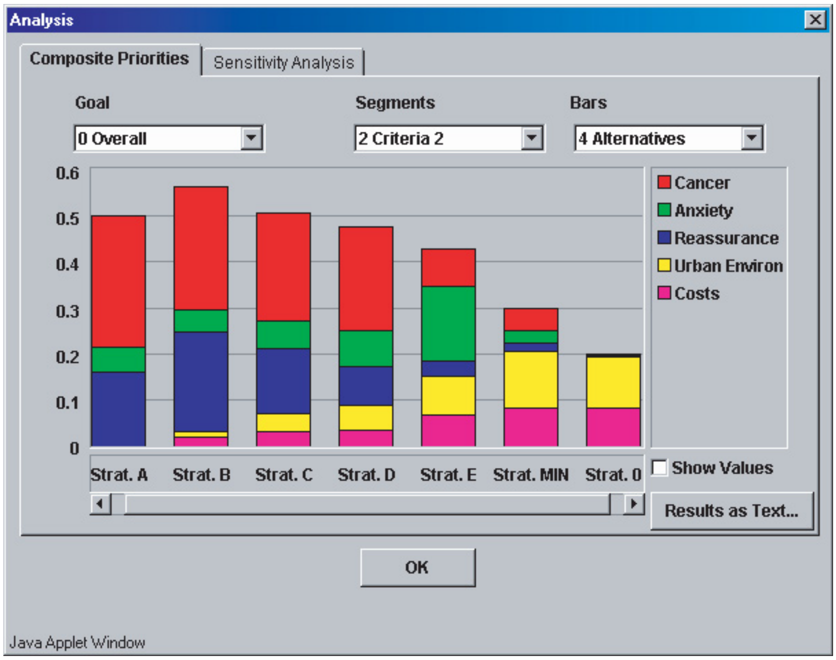


Figure 8.5. Evaluation of strategies by group 5: overall values and sensitivity analysis on Costs.



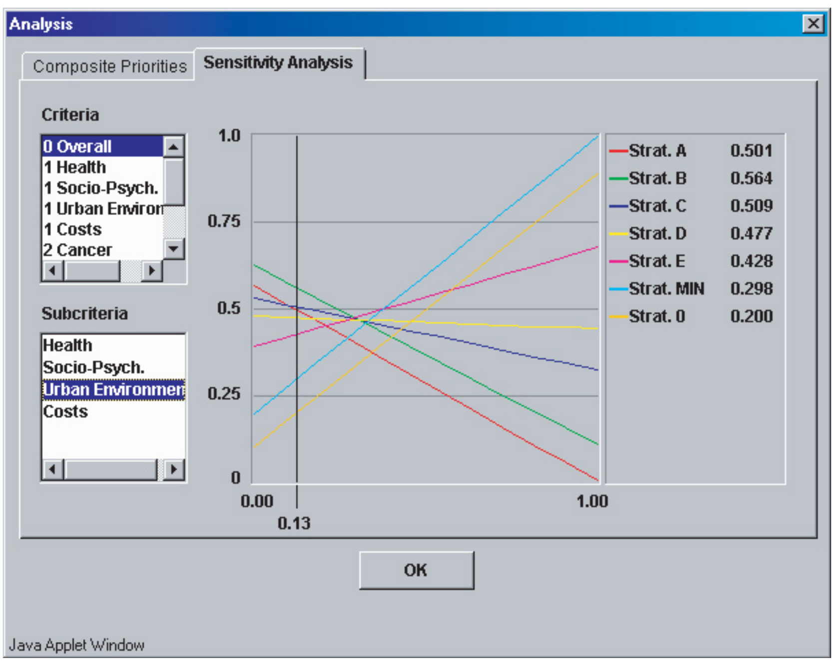


Figure 8.6. Evaluation of strategies by group 6: overall values and sensitivity analysis on Urban Environment.

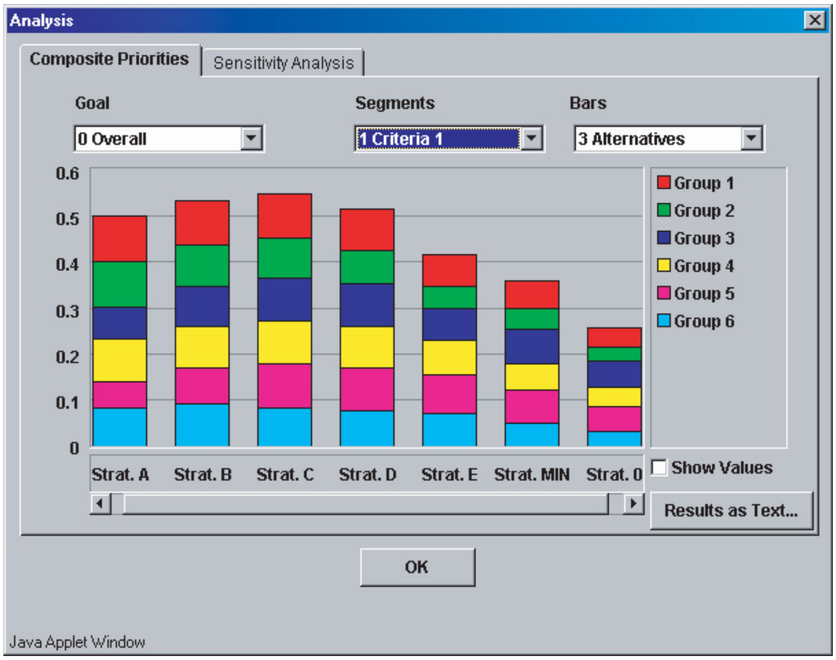


Figure 9. The average overall values of the groups for each strategy.

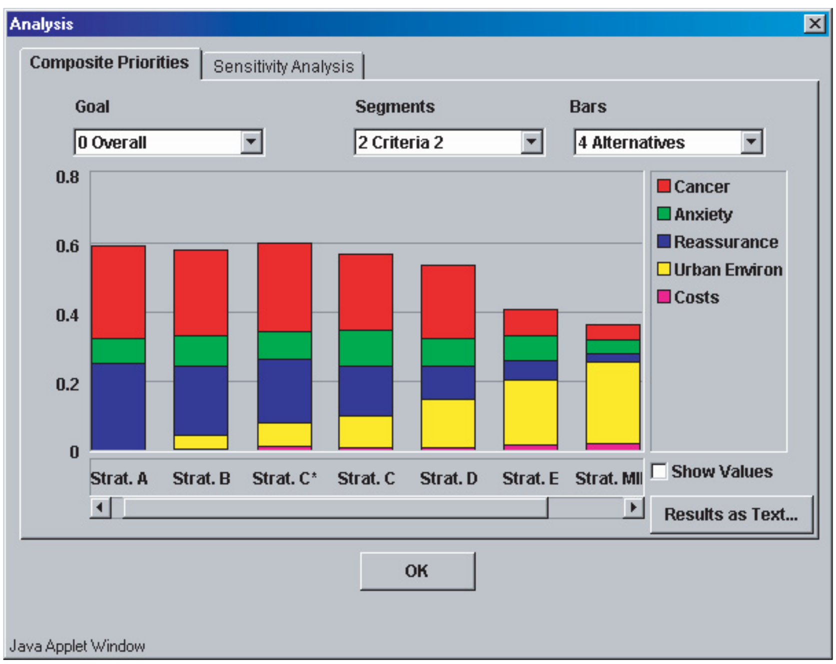


Figure 10. Overall values of the strategies with developed new strategy C*.

Table XVI. The definition of strategies (see also colour codes in Figure 3, p. 20).

Clean-up action	Strategy								
	max	**A**	**B**	**C***	**C**	**D**	**E**	**min**	**0**
Permanent resettlement	L								
Evacuation, days 7–30		L	L	(L)	L	L			
Evacuation, days 7–14							L		
Washing of houses	L++	L++	L++	L+	L+	L	L		
Sweeping of streets	H	H	H	H	L++	L+	L	L	
Pruning of vegetation	L++	L++	L++	L+	L+	L	L		
Cutting grass	H	H	L++	H	L++	L+	L	L	
Scraping of topsoil	L++	L+	L+	L+	L	L			

L comprise Loviisa and eastern part of Pernaja;
L+ comprise in addition to **L**: Liljendal, Lapinjärvi and southern part of Ruotsinpyhtää;
L++ comprise in addition to **L+**: western part of Pernaja, Myrskylä, Askola, Pukkila, Pornainen and Mäntsälä;
H comprise in addition to **L++**: Artjärvi, Orimattila, Kärkölä, Hausjärvi, Riihimäki, Hyvinkää, Porvoo, Sipoo, Järvenpää,
Kerava, Tuusula, Nurmijärvi, Vantaa, Espoo, Kauniainen and Helsinki.

Notes:

- Area NPP will be resettled in every strategy
- Grass will not be cut in areas where surface soil will be scraped
- In Strategy max no cleaning actions will be carried out in area L

Table XVII. The health and costs consequence of strategies.

Attributes	Strategy								
	max	**A**	**B**	**C***	**C**	**D**	**E**	**min**	**0**
Cancer incidents	36	83	94	84	114	120	210	231	261
Saved cancer incidents	225	178	167	177	147	141	51	30	0
Costs of clean-up actions (M €)	22	17	9	14	4	2	1	0	0
Costs of relocation (M €)	5100	16	16	13	16	16	6	0	0
Overall costs (M €)	5122	33	25	27	20	19	6	0	0

Note. The actions taken in the first week are not included in the numbers.

4.5 Evaluation by the participants

At the end of the workshop the participants were asked to fill in a questionnaire (Table XVIII, p. 44). The overall tendency in the replies was that the participants strongly agreed with the statements in the questionnaire. The most modest agreement was in the statement 'all key players including residents of contaminated area should participate in the strategy planning'. As in earlier workshops organised in Finland, all the participants considered that the workshop was useful in general. 12 of 13 participants even fully agreed. All the participants also at least partly agreed that a similar approach could be valuable for training and exercises. The attitude towards an application of the workshop in the case of an emergency was slightly less agreed. It was quite strongly agreed that facilitated workshops should be part of emergency exercises. If this would happen it means that a new culture has been created in the emergency management training.

The format of the facilitated workshop and decision analysis were seen to provide the meeting with useful features. It has been argued in decision analysis literature that decision analysis makes decisions more open and transparent, keeps discussion focused on key issues and helps to understand the views of the other participants. The participants agreed with these arguments. Further, they echoed the view that the analysis reveals the key factors and helps to communicate with the inhabitants, authorities and media. In the literature it has been recognized that the improved communication might sometimes be the most important outcome of the analysis (Kadvany 1995).

Although most participants were not familiar with the Web-HIPRE evaluation software, they felt that it was easy to use the software and to understand the ranking method as well as the sensitivity analysis. This attitude was more positive than in earlier workshops (Ammann et al. 2001). Generally, it was seen that the ranking that emerged from the decision analysis corresponded to intuitive expectations.

Table XVIII. Summary of the feedback from the participants after the workshop by means of the number of participants that agree or disagree with the propositions.

Statement	Fully disagree	Partly disagree	Can't say	Partly agree	Fully agree
All key players (incl. residents of the contaminated area) should participate in the strategy planning.	2	1	1	5	3
The workshop is a suitable approach to form a general view in emergency planning.				4	8
The workshop is a suitable approach to form a general view in a real emergency.			1	7	5
The workshop is suitable for finding an optimal strategy during training and exercises.				4	9
The workshop is suitable for finding an optimal strategy in a real emergency.			4	5	4
The application of the decision analysis made the decision more open and transparent.			2	5	6
Decision analysis keeps discussion focused on key issues and helps to understand the views of other key players.				5	8
Decision analysis reveals the key factors and helps to communicate with the inhabitants, authorities and media.		1		10	2
The information distributed prior and during the workshop was sufficient to understand the situation and to make the best choice.			2	9	1
The workshop method should be a part of emergency exercise.			2	4	7
It was easy to understand the ranking method and use the Web-HIPRE software.		2		7	4
The ranking of the alternatives from the Web-HIPRE analysis corresponds to your own a prior ranking.		1	1	8	3
The sensitivity analysis of model parameters was useful, i.e., it provided more information about the situation decision.			1	5	7
The workshop was useful in general.				1	12

5 Discussion

As in earlier workshops the questionnaire reveals that key players consider this type exercising important, and indeed, a proposal was made to organise workshops regularly as a part of the preparedness. Also, more participants were eager to participate than was appropriate considering the workshop format and the size of the meeting room. One reason is, as noted already in earlier workshops and other exercises, that there is a great desire to consider the later phase issues in nuclear emergency management such as foodstuffs and clean-up actions. This is not the only explanation. The very positive attitude towards the workshop and decision analysis methods could stem from the fact that the participants experience such a structured meeting format useful. The second reason could be that many participants were inhabitants of Loviisa town – local officers as well as residents of Loviisa. The potential victims of a possible accident were planning protective actions which one day could be their real concern. The negative issue is that a lot of time is needed to do all the preparations and the realistic calculations. For example, in this case, despite the experience gained in the earlier workshops, several person months were spent on this new case by the working team. However, we believe that this kind of work will result in new practical approaches and improved preparedness in nuclear emergency management.

The argument on the questionnaire 'all key players including residents of the contaminated area should participate in the strategy planning' was least strongly agreed upon but was still clearly positive. It is a new approach in nuclear emergency management that the affected public actually participates in a fair and competent decision-making process instead of just passively hearing them (Renn et al. 1995; Susskind and Field 1996; Beierle and Cayford 2002). An observation made from this and earlier polls supports the view that a workshop is a suitable approach in the planning phase of a decision making process where all stakeholders with expertise in different areas analyse and evaluate strategies together (Sinkko et al. 2004). Stakeholders and authorities might still be a bit suspicious that public participation could improve decision and thus causing the slight disagreement in the public participation. It could be useful to develop further public participation in similar facilitated workshops.

A finding of our previous workshops was that the relevant key players see one day as a convenient duration for the workshop (Hämäläinen et al. 1998, 2000; Ammann et al. 2001). A shorter time would cause problems, as it is very time-consuming to start from scratch, to define the attributes and assure that all participants understand their meaning similarly. The problem structuring is not an easy task (Belton and Stewart 2002). Therefore, in earlier workshops we have found it useful to create a set of attributes in advance to be discussed in the beginning of the workshop. In the workshop the facilitator stressed the preliminary character of the attributes and urged the participants to revise them whenever necessary. This time we didn't start from a predefined set of attributes but we started with brainstorming, elicited key words and defined their meaning using a text editor. The build up of the value tree was done in less than two hours. As nuclear accidents are rare and all key players are not very familiar with the radiological issues or the decision analysis approach, the process had to be guided by the facilitator in order to assure a suitable set of attributes, i.e., one for which consequence assessments are available. This kind of an approach demands, however, that the facilitator is familiar with the concepts and terminology of nuclear emergency management.

It was quite evident that clean-up actions are not totally independent of evacuation or permanent resettlement in a heavy fallout situation like the one assumed in Loviisa. It was noted that attributes, such as the costs and social disruption, would be important and would differentiate between strategies if long-time population movements are included in the strategies. Once it was concluded that the permanent resettlement is the most recommendable option in the NPP area and one to two weeks evacuation of Loviisa and the eastern part of Pernaja, the ranking of clean-up strategies was dependent only on health, socio-psychological and environment attributes. Feasibility was not considered to be a problem in any of the strategies considered.

During the discussion it was proposed that special plans should be made in advance to be prepared in the case of an emergency. For example, in Loviisa there is no dumping area and yet it is reasonable to dispose the waste generated in the clean-up within the contaminated area. A new or a temporary dumping area can not be planned in a short time but planning in advance is needed.

During the final discussion it was asked whether the analysis and engaged dialogue have helped to understand the health risks. In the literature it has been found that those people who participate in planning or mitigation actions perceive the risk to be lower than those who do not participate (Arvai 2003). Susskind and Field (1996) and Slovic (1997) have also proposed that public involvement improves risk management and risk communication. During the process the consequences of different actions are assessed and the risks can be easily compared. The risks were seen to be better comprehended by the participants. Hence the facilitated workshops could also have a role in risk communication, helping the population to assess their risk attitudes realistically.

The facilitated workshop method could be very successful in improving the quality of the decision and resolving conflicts among competing interests of key players. It could motivate the participants and enhance the quality of the deliberation, and the degree of the public control could be set by public participation (Sinkko et al. 2004). There is a danger that the participation of a small group tends to narrow down the incorporation of public values in the decision, and the education and informing of the public (Beierle and Cayford 2002). Attention should be paid to the responsibility of participants in intensive communication to those whose spokesman they are. A method to assure a wider public participation in the future would be to conduct the decision analysis on the Internet.

6 Conclusions

In the discussion we already pointed out that these kind of facilitated workshops are of real value. The main benefits include an improved understanding of the real risks, policy alternatives and stakeholders' perceptions that are likely to emerge in a large nuclear accident. Our current group of participants represented the high level of both the governmental and the local authorities and stakeholders. Workshops like this help to create a shared vision of the risks, realistic countermeasure policies and preparedness needs. Our workshop confirmed the earlier conclusions about the general usefulness and feasibility of the approach but also some new observations were made.

There should be a general discussion about the ranges of the effects of radiation risks in general and a comparison of accident consequences with other risks. This was done in our workshop with a summarizing page "How much is much" and a short presentation followed by a discussion. For example, in that very area of Finland, radon gas generated in the rock of the ground finds its way into houses and causes significant health risks comparable with the risks caused by the major nuclear accident of this scenario.

One interesting observation was that acceptability or feasibility issues related to extensive measures did not turn out to be critical in Finland. It was not these direct problems that mattered but the indirect concerns included in the attributes of anxiety and credibility. This is a phenomenon which is likely to reflect the culture of governance in various countries.

Another conclusion is that the participants easily learn to use the Web-HIPRE decision analysis software. It was clearly noticed that the personal interactive analysis of individual trade-offs helped to strengthen the participants' views on the importance of factors in the case. Also the resulting priority weights created a means to communicate about the strategies which were found feasible.

The final conclusion is that such workshops should be part of the permanent safety practices of the authorities as they provide a way to learn the communication of needs and to get a comprehensive overall view of potential problems in major accidents.

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